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Economic Impact of Spotted Wing Drosophila (Diptera: Drosophilidae) Yield Loss on Minnesota Raspberry Farms: A Grower Survey

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Abstract

Minnesota was dubbed the 'raspberry consumption capital of America' in 2017 by wholesaler Driscoll's, Inc. Local production of this high-demand fruit, however, is limited by the invasive pest, spotted wing Drosophila (*Drosophila suzukii* Matsumura, Diptera: Drosophilidae). Recent research to develop integrated pest management (IPM) programs for MN berry crops indicates that raspberry growers are particularly vulnerable to significant spotted wing Drosophila-related yield losses. Spotted wing Drosophila was detected in Minnesota in 2012 across 29 counties. This analysis explores the economic impact of raspberry yield losses associated with spotted wing Drosophila in Minnesota as part of a multifaceted research initiative. An electronic survey of 157 MN berry growers was conducted in November 2017. Eighty-two individual grower surveys were returned (52% response rate). The survey included questions about production acreage, marketing practices, spotted wing Drosophila-related yield losses and future production intentions. The results of the e-survey indicate that raspberry growers have borne the highest levels of infestation among MN fruit growers surveyed. Spotted wing Drosophila-related yield losses for raspberry growers ranged from 2 to 100% of planted acreage. The median yield loss for this group of growers was 20% in 2017. Applying the median yield loss to ex-ante production estimates, we conclude that MN growers lost approximately $2.36 million in raspberry sales during the 1 yr studied. Investing in spotted wing Drosophila control measures will help MN growers reduce some of these losses in the future.

Key words: survey, spotted wing Drosophila, invasive fruit fly, raspberry yield loss

Raspberry consumption is on the rise nationwide and may offer a promising seasonal niche for MN bramble growers looking to market 'locally-grown'. The Economic Research Service estimates that fresh raspberry utilization has grown steadily nationwide from 0.18 pounds per capita in 2007 to 0.86 pounds per capita in 2016 (USDA, ERS). A recent press release from Driscolls, Inc. (Watsonville, CA), however, suggests that this utilization estimate, while impressive, is undervalued for Minnesota. Drawing on Nielsen Company data, Driscoll's, Inc. reports that 'Twin Cities' households (Minneapolis-St. Paul metro area) consumed 132% more fresh raspberries on average than U.S. households explaining why the company named Minnesota 'raspberry consumption capital of America' in July 2017 (Duan 2017).

Combining USDA raspberry utilization estimates with Nielson data, we estimate that Minnesotans utilized approximately 5.6 million pounds of fresh raspberries and another 4.9 million pounds of frozen raspberries in 2017. Fresh and frozen raspberries are priced differently in wholesale and retail markets. However, due to data limitations, we apply the USDA 2017 median retail price for nonorganic raspberries, $6.70 per pound, to both fresh and frozen raspberries. We estimate the annual retail value of statewide of fresh and frozen raspberries at $70.6 million (value = utilization * price per pound) (Table 1). Recognizing that the MN growing season (USDA plant hardiness zone 3b-4a) is approximately 4 mo, we estimate seasonal demand for fresh and frozen raspberries is 3.51 million pounds valued at $23.5 million (Table 1). Minnesota growers' potential to capture local, seasonal raspberry demand, however, is limited by the recent invasive pest, spotted wing Drosophila (*Drosophila suzukii* Matsumura, Diptera: Drosophilidae), which has been shown to favor raspberries as a host fruit (Asplen et al. 2015, Holle et al. 2017) (Fig. 1). Spotted wing Drosophila deposits eggs in raspberry druplets using a serrated ovipositor. As larvae begin to grow, raspberry fruit degrade and become soft and discolored, making them unmarketable (Figs. 2 and 3).

Table 1. Raspberry utilization in Minnesota, 2017

	MN outstate	Twin-cities MSA[a]	MN statewide
Population[b]	2,090,039	3,360,829	5,450,868
Fresh raspberry utilization (lbs per person)	0.86	1.14[f]	
Fresh raspberry utilization (lbs)[c]	1,797,434	3,831,345	5,628,779
Frozen raspberry utilization[d] (lbs per person)	0.90	0.90	
Frozen raspberry utilization (lbs)	1,881,035	3,024,746	4,905,781
Annual raspberry utilization (lbs)	3,678,469	6,856,091	10,534,560
Median Midwest nonorganic retail ($ per lb)[e]	6.70	6.70	6.70
Annual retail value ($)	24,645,742	45,935,809	70,581,552
Seasonal (4 mo) utilization (lbs)	1,226,156	2,285,364	3,511,520
Seasonal (4 mo) retail value ($)	8,215,245	15,311,938	23,527,184

[a]The 'Twin Cities' is defined as the Minneapolis-St.Paul-Bloomington MN-WI Metropolitan Statistical Area (MSA).

[b]Source: US Census Bureau, American Fact Finder, 2017 Population Estimates.

[c]Source: USDA (2018b), ERS. 'Table G-13-Fresh raspberry supply and utilization, 1992 to date.' *Fruit: US supply and utilization: fresh, canned, juice, dried; per capita use, US population.*

[d]Source: USDA (2018c), ERS. 'Table G-38-Frozen fruit, per capita use, product weight basis, 1980 to date.' *fresh, fruit and tree nut yearbook tables.*

[e]We recognize that fresh and frozen raspberries are valued differently. However, due to data limitations, we price them equally using USDA 2017 Midwest median raspberry prices. Source: USDA (2018a), Agricultural Marketing Service, 'Weekly Advertised Fruit & Vegetables Retail Prices.'

[f]Neilson data suggests that 'Twin Cities fresh raspberry consumption' is 132% higher than national average per capita consumption. The MN Twin-Cities consumption estimate was adjusted by 132% to arrive at the Twin-Cities per capita consumption estimate for fresh raspberries.

Table 2. Estimated MN raspberry production, before spotted wing Drosophila detection

	2007 acres#	2008–2009 yield lbs/acre	Ex-ante production[d] lbs
Baseline production	296	4,708	1,393,568
Certified organic			
Red, open field	5[a]	1,307[a]	6,535
Nonorganic			
Red, open field	254	4,708[b]	1,195,832
Black, open field	13	2,000	26,000
Red, high tunnel	24[c]	22,253[b]	534,072
Adjusted production	296		1,762,439[e]

[a]Raspberry production reported is assumed to be open-field. Source: 'Table 25: Organic berries harvested from certified organic farms: 2008.' 2008 Organic Production Survey. USDA, National Agricultural Statistics Service.

[b]Two-year-old, nonorganic plants produced in USDA hardiness zone 3b. Estimated based on 2009 data from field research at NCROC in Grand Rapids, MN. Source: Yao and Rosen 2011.

[c]Calculated using primary data from 2017 e-survey. High tunnel production estimated to be equal to 8.3% of nonorganic raspberry production. All high tunnel production in 2017 was reported as nonorganic. The same production ratio was applied to ex-ante spotted wing Drosophila production years.

[d]Production = acres*yield where yield is measured as pounds per acre.

[e]Total MN production of organic and nonorganic raspberries.

Table 3. Percent of MN fruit growers using alternative production methods

n = 82	Raspberry growers	Strawberry growers	Blueberry growers	Other fruit growers
Open field	90%	90%	91%	100%
High tunnel	8%	3%	5%	0%
Other	3%	8%	5%	0%

This analysis explores economic losses for MN raspberry growers due to spotted wing Drosophila-related yield reductions. Spotted wing Drosophila-related yield loss estimates have been applied to raspberry production estimates to quantify the value of these losses in California for nonorganic (Goodhue et al. 2011) and organic raspberries (Farnsworth et al. 2017) using USDA production data. Raspberry production (total pounds) is a function of acreage (number of acres) and crop yield (pounds per acre). Yield is affected primarily by plant variety (summer-bearing vs fall-bearing); plant maturity (less than 3 vs 3 yr or more); growing conditions (open-field vs high tunnel [HT]); and management practices (organic vs nonorganic), all else being equal. Data for nonorganic raspberry production in Minnesota, however, are not compiled by USDA as the state is considered a relatively small producer of bramble fruit.

The USDA compiles statistics for harvested raspberry acreage in MN every 5 yr for the Census of Agriculture; however, it does not compile yield estimates. Consequently, the size and value of Minnesota's nonorganic raspberry crop is currently unknown. MN production estimates were needed to quantify the value of spotted wing Drosophila-related yield loss. We first estimated production in the ex-ante period (before spotted wing Drosophila was detected) then applied yield loss rates obtained from an electronic survey conducted as part of this research to quantify spotted wing Drosophila losses.

Economic losses are estimated using primary survey and field research data as well as USDA census data. We do not include the cost of material inputs and labor associated with spotted wing Drosophila control here. These will be addressed in a forthcoming paper. Instead, for simplicity, we assume that there is no widespread management in place among MN growers to effectively control the pest and that there is no increase in the price of raspberries due to a reduction in local supply (Bolda et al. 2010 and Goodhue et al. 2011). This last assumption is supported by findings that berries from other geographic areas can be imported to fill local supply gaps and that other berries are considered 'raspberry substitutes' (Sobekova et al. 2013). The information in this article will assist Minnesota's raspberry growers, industry suppliers, researchers and policy makers interested in weighing the costs and benefits associated with spotted wing Drosophila control.

Table 4. Spotted wing Drosophila-related yield losses for fruit crops reported by MN survey respondents

n = 82	Raspberries	Strawberries	Blueberries	Other
Median	20%	5%	5%	0%
Mean	30%	13%	16%	17%
Low	2%	1%	2%	1%
High	100%	90%	54%	100%

Table 5. Spotted wing Drosophila-related raspberry yield losses reported by MN survey respondents

n = 28	Organic raspberries	Nonorganic raspberries
Median	20%	20%
Average	27%	25%

Methods and Materials

Production Estimates

We use a combination of primary and secondary data to quantify statewide MN raspberry production before spotted wing Drosophila detection (ex-ante period). We chose the 2007–2009 yr to represent the ex-ante period as they are the most recent years for which organic raspberry data are available before detection of spotted wing Drosophila in MN. USDA harvested acreage estimates from the Census of Agriculture are paired with primary yield data.

Yield data for nonorganic open-field and nonorganic HT conditions were obtained from 2008 to 2009 field trials conducted by the University of Minnesota's North Central Research and Outreach Center (NCROC) in Grand Rapids, MN (USDA plant hardiness zone 3b; Agricultural Research Service, https://planthardiness.ars.usda.gov/PHZMWeb/). We report the NCROC yield data average for five different cultivars of fall-bearing, 3-yr-old plants. Average open-field nonorganic yield was 4,708 pounds per acre. Average HT, nonorganic yield was 22,253 pounds per acre over the same period (Yao and Rosen 2011). For reference, commercial raspberry yields among the country's top producers, in California, Oregon, and Washington, were 18,000 pounds per acre, 5,080 pounds per acre and 6,400 pounds per acre, respectively (USDA 2007). No distinctions are made in data reported for the West Coast states between open-field and HT growing conditions. Therefore we assume that the yield estimates for California, Oregon, and Washington represent a mix of production methods.

Table 6. MN raspberry yield loss estimates due to spotted wing Drosophila-related infestation

Spotted wing Drosophila-related yield loss	Organic raspberry loss (lbs)[a]	Nonorganic raspberry loss (lbs)[b]	Total raspberry loss (lbs)
Adjusted production	6,535	1,755,904	1,762,439[c]
20% loss	1,307	351,181	352,488
30% loss	1,961	526,771	528,732
60% loss	3,921	1,053,542	1,057,463

[a]Represents organic red raspberries grown in open-field conditions.
[b]Represents nonorganic red raspberries produced in open-field, black raspberries produced in open-field, and red raspberries produced in high tunnels.
[c]Represents MN raspberry production in 2007 before spotted wing Drosophila was detected in the state.

Table 7. Revenue losses to MN raspberry industry due to spotted wing Drosophila-related infestation

Spotted wing Drosophila-related yield loss[a]	Organic raspberry revenue loss ($)[b]	Nonorganic raspberry revenue loss($)[c]	Total raspberry revenue loss ($)
Adjusted revenue	60,841	11,750,460	11,811,301
20% loss	12,168	2,350,092	2,362,260
30% loss	18,252	3,525,138	3,543,390
60% loss	36,505	7,050,276	7,086,781

[a]Applied to 2007 ex-ante yield estimates from Table 2.
[b]Median weighted average Midwest organic retail price in 2017 is estimated to be $9.31/lb. Source: USDA, Agricultural Marketing Service, 'Weekly Advertised Fruit & Vegetables Retail Prices.' Accessed 5 February 2019.
[c]Median weighted average Midwest nonorganic retail price in 2017 is estimated to be $6.70/lb. Source: USDA, Agricultural Marketing Service, 'Weekly Advertised Fruit & Vegetables Retail Prices.' Accessed 5 February 2019.

Regarding organic data, raspberry acreage and yield are available for certified organic and organic-exempt growers in Minnesota as part of the annual USDA Organic Production Survey. Data from this secondary source are used to quantify ex-ante organic raspberry production using 2008 data; there was no distinction made between open-field and HT production in the survey. Therefore it is assumed that all organic production measured comes from open-field conditions. Average certified organic yield was 1,307 pounds per acre in 2008 (USDA 2008). Using newly calculated nonorganic and organic production estimates, we applied a sensitivity analysis for yield loss to determine spotted wing Drosophila impact on seasonal raspberry production and local raspberry sales. Yield loss estimates came from a primary survey developed for this research.

Survey Design and Distribution

A 12-question survey was designed to better understand the economic impact of spotted wing Drosophila on MN fruit growers during the 2017 production year. Survey questions addressed production practices, marketing channels, spotted wing Drosophila infestation, spotted wing Drosophila-related yield loss, spotted wing Drosophila control measures used and future production plans. Questions were formatted with multiple choice single answer options, multiple choice multi-answer options and open text write-in responses. Before survey release, all questions were reviewed and tested for validity with five faculty members and students representing the Department of Applied Economics, the Department of Entomology and the Department of Horticulture at the University of Minnesota. The questionnaire, built and administered using Qualtrics software (Seattle, WA), was distributed to 157 Minnesota fruit growers on 10 November 2017. Two follow-up reminders were sent electronically on 17 and 20 November. Fruit grower contacts were supplied by the Minnesota Department of Agriculture's *MN Grown Program*. The survey was completed by 82 individual growers (52% response rate). Forty-five of the respondents (55%) produced raspberries in 2017.

Table 8. MN raspberry grower production intentions due to spotted wing Drosophila infestation, 2017

n = 49	Number	Percent
Will reduce acreage ('probably' or 'definitely')	12	24.4
Will not reduce acreage ('probably' or 'definitely')	27	55.1
Not sure	10	20.4

Results and Discussion

The USDA Census of Agriculture reported that 281 MN farms grew raspberries on 296 harvested acres in 2007 (1.05 acres/farm). Raspberries represent the second largest berry crop in Minnesota (strawberries are number one). Using the USDA acreage data and NCROC field-trial yield data, we estimate MN's raspberry production before spotted wing Drosophila detection (2007-09) at 1,393,568 pounds (4,708 lbs per acre * 296 acres). This is depicted as 'baseline production' in Table 2 and assumes that all of MN's raspberry acreage is nonorganic, grown in open-fields using high-yield red varieties and represents the total harvest (some of which may be considered unmarketable by retailers). Next, we adjusted for management practices (organic, HT) and cultivar differences. The USDA Organic Production Survey suggests that five acres of raspberries were produced on certified organic land in Minnesota and yielded 1,307 pounds of raspberries per acre in 2008. Total certified organic production of fresh raspberries in Minnesota was estimated at 6,535 pounds in 2008 (Table 2).

We also know from the 2017 e-survey that while the majority of MN raspberries were grown in open fields, approximately 8% were grown in higher-yielding HTs (Table 3). We apply the same rate of HT production to the ex-ante production years and estimate that 24 acres of MN raspberries reported in the Census of Agriculture may have been cultivated under HT conditions in 2007. Utilizing the NCROC HT yield observations for nonorganic raspberries, 22,253 pounds per acre, we quantify MN's ex-ante HT production at 534,072 pounds (Table 2). Write-in e-survey responses also suggest that lower-yielding black varieties were grown in open-field conditions on approximately 4% of raspberry acreage. We applied these estimates to the baseline production numbers and calculated that 13 acres of black raspberries were grown in Minnesota yielding 26,000 pounds in 2007 (Table 2). With management and varietal adjustments applied, baseline fresh raspberry production estimates for Minnesota were calculated at 1,762,439 pounds and defined as 'adjusted production' for the remainder of this report (Table 2).

Next, a sensitivity analysis is applied to aggregate raspberry production and crop values (from Table 2) using spotted wing Drosophila-related yield loss rates reported in the survey to estimate the quantity and value of raspberry crop loss.

The results of the e-survey indicate that raspberry growers have borne the highest levels of infestation among Minnesota fruit growers surveyed. Raspberry yield losses attributed specifically to spotted wing Drosophila infestation ranged from 2 to 100% of

Fig. 1. Spotted wing Drosophila female (left), with serrated ovipositor highlighted; male (right), with distinctive spots on wings (C. Guedot, University of Wisconsin-Extension).

Fig. 2. Spotted wing Drosophila adults on raspberry with druplets damaged by larval feeding; within hours, fruit degrades, and becomes unmarketable (S. Wold-Burkness, University of Minnesota).

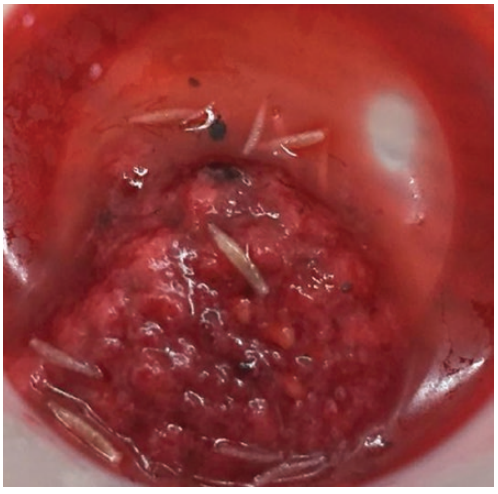

Fig. 3. Multiple spotted wing Drosophila larvae feeding within raspberry (S. Wold-Burkness, University of Minnesota).

planted acreage among those surveyed with a median yield loss of 20% in 2017 (Table 4). This occurred despite 74% of growers actively managing to control spotted wing Drosophila. Controls included conventional, nonorganic pesticides; organic biocontrols; sanitation; physical exclusion and mass trapping. Median reported MN yield losses are well below initial spotted wing Drosophila-induced raspberry yield loss estimates of 50% in California that were observed prior to implementation of spotted wing Drosophila management controls. Following the introduction of effective spotted wing Drosophila chemical controls, on-farm trapping in CA suggested that nonorganic raspberry yield losses fell from 10% in 2011 to less than 1% during 2012. At the same time, however, organic raspberry growers in CA experienced consistent annual yield losses of 12% during 2011–2012 due to ineffective spotted wing Drosophila control measures (Farnsworth et al. 2017). The relatively high spotted wing Drosophila-related yield losses reported by MN growers (compared to yield losses reported by CA growers) may be explained by the later detection of spotted wing Drosophila in Minnesota and the use of less aggressive spotted wing Drosophila controls by MN growers.

Spotted wing Drosophila yield loss rates of 20, 30, and 60% are assumed in the analysis. These are equal to the observed median loss rate for organic and nonorganic survey respondents (20%), the average loss rate for organic and nonorganic growers (30%) and the average loss rate of growers who reported more than a 20% loss (60%, Table 5). The median yield loss is equal to 352,488 pounds of organic and nonorganic raspberry production for 1 yr (Table 6). We applied 2017 median retail prices for certified organic and nonorganic raspberries, $9.31 per pound and $6.70 per pound, respectively, to calculate the retail value of raspberry production losses. Organic prices were compiled by USDA using 5,752 retail price observations while nonorganic prices were compiled using 40,172 observations in 2017. A 20% yield loss would have led to approximately $2.36 million in reduced sales for 1 yr. A 30% yield loss, the average reported by Minnesota raspberry growers, would have resulted in overall sales losses of $3.54 million. If we assume a 60% yield loss, raspberry sales revenue would have declined by over $7.09 million annually (Table 7). Given the production loss

Fig. 4. Experimental high tunnel covered with standard poly, and fine mesh exclusion netting on each end (E.C. Burkness, University of Minnesota).

estimates and the economic value of calculated losses, it may come as no surprise that some Minnesota raspberry growers planned to reduce acreage in 2018. Approximately 24% of raspberry growers surveyed said they would 'probably' or 'definitely' reduce acreage as a result of spotted wing Drosophila infestation while 55% said they 'probably' or 'definitely' would not reduce acreage. The remainder of those surveyed were undecided (Table 8).

Conclusions

Relatively little US research has been completed estimating spotted wing Drosophila-induced yield and revenue losses for raspberries and other soft fruits. The survey work presented here, along with the work pioneered by Farnsworth et al. (2017), contribute to a better understanding of the economic impact of spotted wing Drosophila. This article presents results from the first US grower survey on spotted wing Drosophila infestation and yield loss. Survey results were used to quantify raspberry production before spotted wing Drosophila detection in Minnesota, yield loss related to spotted wing Drosophila in 2017 and the resulting annual revenue losses for the MN raspberry industry.

Our calculations suggest that the MN raspberry industry produced approximately 1.76 million pounds of raspberries annually before spotted wing Drosophila detection. Assuming a 20% reduction in yield due to spotted wing Drosophila infestation (the median loss rate reported in 2017) we conclude that MN growers and retailers lost approximately $2.36 million in raspberry sales over a 1-yr period (Table 7).

Responding swiftly to spotted wing Drosophila with effective control measures for organic and nonorganic growers will reduce annual losses. Combining the value of production losses (equal to $2.36 million in 2017) with the opportunity costs associated with foregone sales in the 'raspberry consumption capital of America' (equal to $23.52 million in seasonal utilization in 2017, Table 1) we suggest that MN input suppliers, growers, and retailers would benefit economically from a significant investment in improved spotted wing Drosophila management strategies. For example, in addition to continuing to evaluate alternative and organic-certified insecticides for spotted wing Drosophila control, further research is warranted to assess the use of canopy management, alternative harvesting schedules, and/or fine-tune the use of exclusion netting, with and without HT systems (Asplen et al. 2015, Leach et al. 2016, Rogers et al. 2016) (Fig. 4). Initial research suggests that exclusion netting may be particularly valuable for raspberry growers given the high value of the crop, but also the vulnerability of raspberries to spotted wing Drosophila infestation in Minnesota (Rogers et al. 2016, Holle et al. 2017). A recent economic analysis in Italy also found that exclusion netting could be a key component of an improved IPM program for spotted wing Drosophila, and offered high net returns (Del Fava et al. 2017). Forthcoming research into material and labor costs associated with spotted wing Drosophila will further inform the discussion about how much growers are currently investing to manage spotted wing Drosophila and the cost–benefit of additional spotted wing Drosophila-related R&D.

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